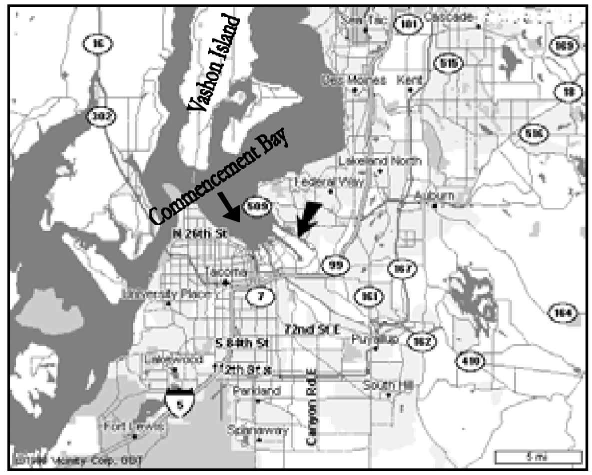
USG/Thermafiber

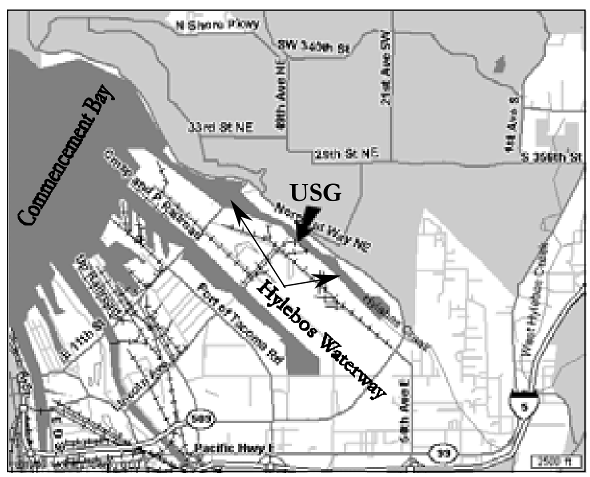
Address: **2301 Taylor Way, Tacoma**
Region: **Hylebos Waterway, Commencement Bay**
Designer: **AGI Technologies**
Contractor:
Owner: **Thermafiber LLC**
Shoreline Type: **Industrial Canal**
Project Type: **CERCLA Restoration**
Re-grade, Gabion Mattresses
Wave Energy: **Very Low**
Tides: **MHHW: +11.84**
Extreme High: +14.9
Extreme Low: -3.84
Cost: **N/A**
Date Completed: **August 1997**



Location: USG in Commencement Bay

Site History / Description

The USG / Thermafiber site is a 9.4 acre parcel located on the southwestern shore of the Hylebos Waterway in the Commencement Bay Nearshore Tideflats Area (Tacoma, Washington).

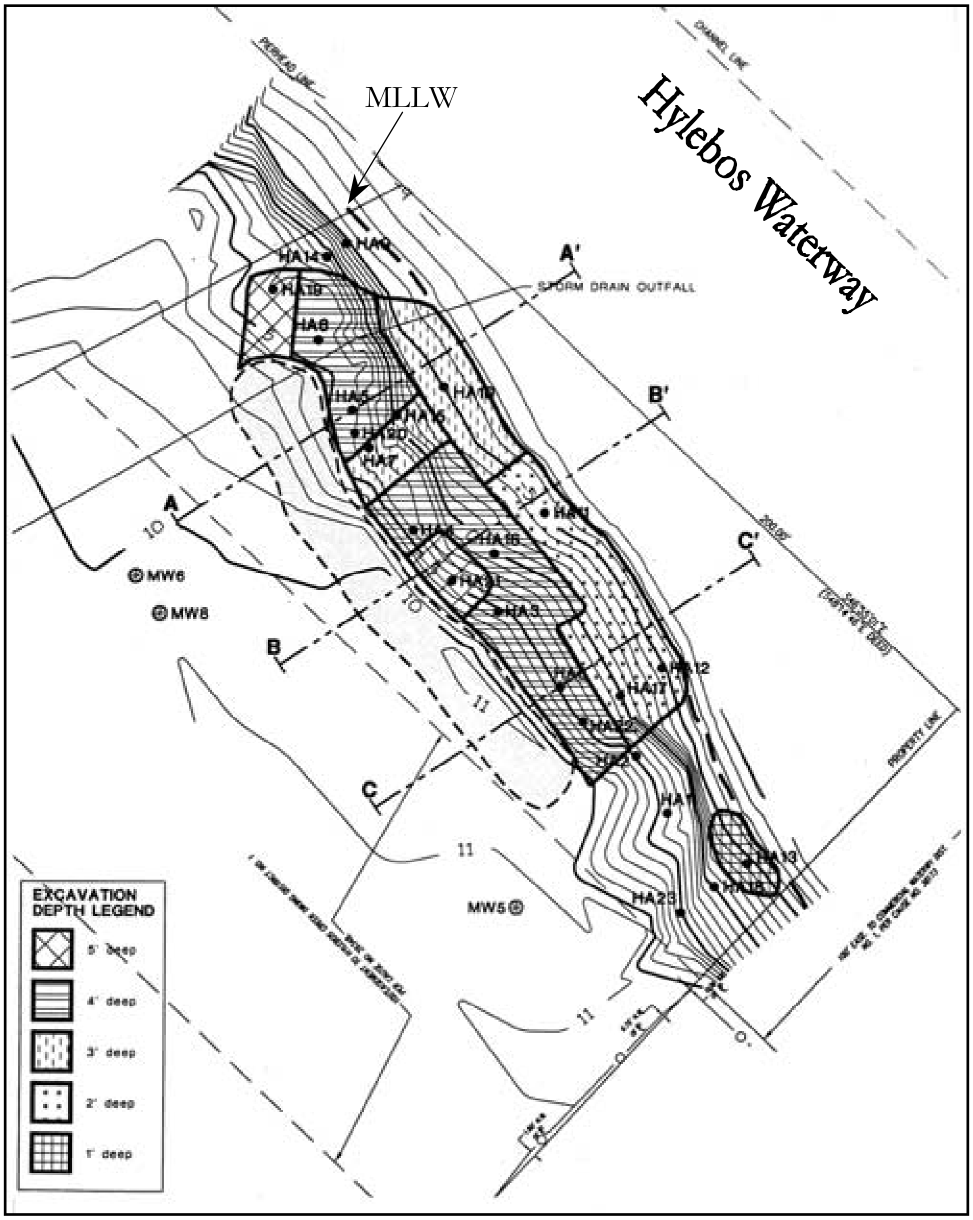


Location: USG on Hylebos Waterway

The USG Corporation owned the site from 1959 through the spring of 1996 when they sold it to Thermafiber LLC. The plant on site is used to produce mineral fiber insulation ("rock wool"). In this process slag from iron production and basalt are heated and spun out into a product that looks much like fiberglass insulation. While USG owned the plant contaminated slag was used and the byproducts of production were disposed of in the Hylebos. The location was declared a CERCLA site because the upland and intertidal soils had concentrations of metals exceeding cleanup levels. Cleanup and restoration was performed in the summer of 1997.

Project Description

The USG project was complicated by the fact that it was a CERLA site. Unlike the Indian Island and Floral Point projects, USG started with a large excavation component. Following the removal of



USG / Thermafiber: Site and excavation plan.

contaminated sediments, the site was backfilled and then erosion protection measures were installed. Remediation began with the removal of 1,072 tons of material from the upland zone and 2062 tons from the intertidal slope area.

The upland area was backfilled with quarry spalls, pit run sand and gravel and topsoil. The spall was used where the excavation went below the water tale. This was then covered with sand and gravel. At this point the fill was compacted to the proposed grade. The sand and gravel was then covered with a layer of topsoil to support revegetation.

The intertidal slope was approached differently. The backfill began with an even, thin layer of quarry spall tamped into the silt/clay bank. This created a structural interlock between the silt clay and the pit run sand and gravel that followed. The original plan called for a layer of geotextile fabric instead of spalls. The plan had to be modified, however. Silt and clay had not been expected. If they had used the geotextile an artificial slip plane would have been created in the bank. The sand and gravel was used to bring the slope up to grade and to create a habitat bench. The height for this bench was set to match that formed by a clay layer immediately to the northwest. The design sought to preserve this existing bench because it was covered with healthy pickleweed. The sand and gravel mix was followed by a layer of geotextile fabric (filter fabric). This fabric allows water to pass through (ensures that hydrostatic pressure does not build up) but retains fine sediments. The next layer was a 9" gabion mattress. This was composed of PVC coated wire mesh baskets that are 12'x6'x9". These were laid down and wired together in rows running parallel to the Hylebos waterway. The baskets are designed to last a minimum of 20 years. The gabion revetment was covered with 6"-8" of topsoil. Large woody debris and rocks were placed on the bench to improve the habitat and aid revegetation.

Monitoring

No official monitoring plan is in place. A band of the gabions have become exposed since the project was finished. This area is approximately 8' wide and runs most of the width of the site. There has also been significant settlement by seaweeds on the exposed baskets.

Success

The project is too new and there is too little information available from which to judge success. One of the key objectives of this project was to enhance habitat by creating a bench at the appropriate upper intertidal elevation. The ultimate success of this project will depend to a large extent on how well the bench is colonized by intertidal and riparian vegetation. Another indicator of success will be the extent to which fine sediment is retained in the lower part of the gabion slope and the degree to which the infauna within this fine sediment reflects the biota found on unaltered shorelines in the vicinity.

The gabion baskets have been exposed on the waterward edge of the bench (Figure 4). This does not indicate any serious problem for the project, only that the intertidal slope may have been too steep. The geometry was constrained by the inflexibility in moving the shoreline landward and by space required by the bench itself.

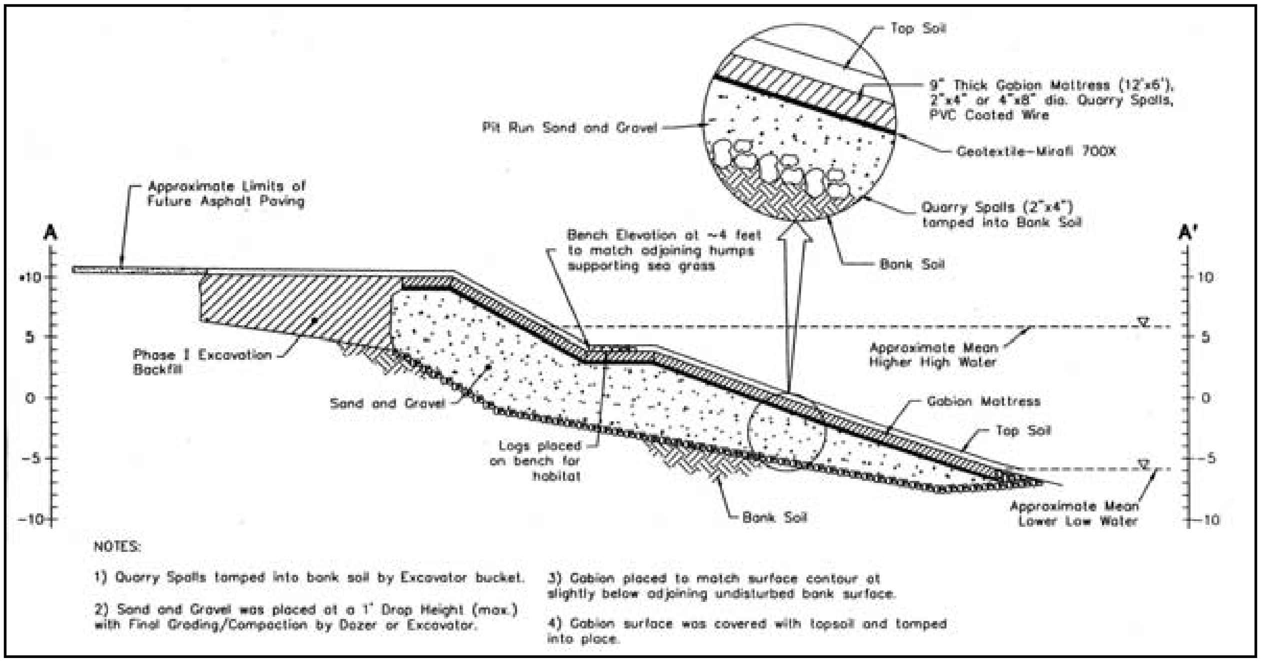
Alternatives Considered

The alternatives for this project included using rock instead of gabions and using gabions but not constructing a habitat bench. Neither of these made it to the design stage, however.

Contacts

Washington Department of Fish and Wildlife:	J. Boettner (now with WA. State DNR)
Department of Ecology:	J. Mercuri
AGI Technologies.:	M. Carlson

Project Design Profile



Profile: USG/Thermafiber

Figure 1. View south of site prior to construction. Note vegetated upper intertidal benches.

Figure 2. View southwest of site after construction. Fine sediment covers gabion mattresses except in area immediately below bench (people standing).

Figure 3. Installation of gabion mattresses over geotextile (*Photo: Joyce Mercuri)*

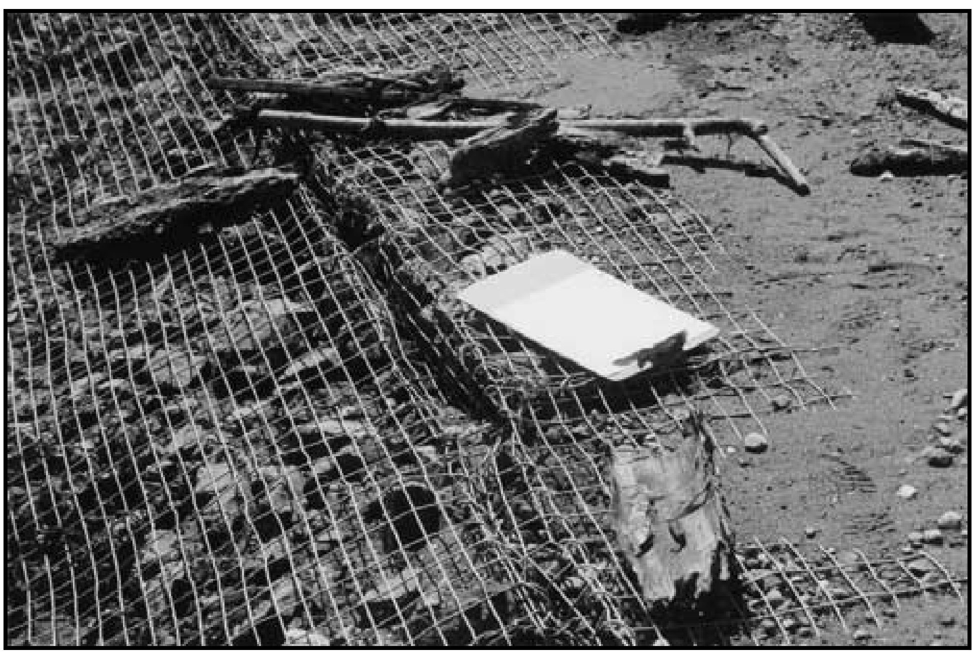


Figure 4. Detail at waterward edge of bench showing exposure of gabions.

Weather Watch Park

Address**: 4035 Beach Dr. SW, Alki Beach**
Region**: West side of Alki Beach**
Designer**: Lezlie Jane (for the Alki Community Council)**
Contractor**: Lezlie Jane**
Owner**: Seattle Engineering Department**

Shoreline Type**:**	**Historic Beach**
Project Type**:**	**Opportunistic beach.**
Wave Energy**:**	**Very Low**
Tides**:**	**MHHW: +11.40** **Extreme High: +15.0** **Extreme Low: -4.5**
Cost**:**	**$87,000 + in kind contributions (includes benches, column etc)**
Date Completed**:**	**Summer 1991**

Location: Weather Watch Park on Alki Beach

Site History / Description

Weather Watch Park is technically a Seattle street end. In 1907, the site was a ferry dock for the mosquito fleet. When service was discontinued in 1920, the dock was dismantled and the site became a vacant lot. Some rubble accumulated on the site as did a large supply of coarse woody debris. The site is immediately adjacent to Beach Drive and is 135' long. There is a small upland area between the road and a seven-foot bank that leads down to the beach.

In 1990 the Alki Community Council organized the local public and in 1991 they created Weather Watch Park. The project was performed to improve the local community but serves as a perfect example of what is possible, even with a small site in a heavily armored area.

Project Description

Weather Watch Park is not an example of a project designed to resist erosion as much as one designed to avoid erosion. The project began by removing rubble that had accumulated on site over the course of seventy years as a vacant lot. The bank was not regraded or reconstructed -- it was only reinforced with several large rocks. The woody debris was not placed on site -- it is what accumulated naturally in the pocket beach. Once the bank was cleaned up, extensive revegetation was performed. Paths down to the beach were built and a park like atmosphere was created in a small area at the street level.

The entire project is set at least 30' farther back than the vertical cement bulkheads on either side. This is a significant factor contributing to the effective accumulation of sediments and drift logs, as well as the protection of the bank itself from wave erosion.

Monitoring

There is no monitoring plan in place. The site has been stable for eight years.

Success

Weather Watch Park is stable, despite the fact that it is located in a zone of relatively high wave energy and is flanked by heavy armoring. The project stands out in this report, not due to technological sophistication, but simply as an example of what is possible on a single property if the physical processes are allowed to establish a natural equilibrium.

Alternatives Considered

N/A

Contacts

Alki Community Council	L. Jane
Bart Berg Landscaping:	B. Berg

Figure 1. View south of Weather Watch Park. Note vegetated bank and drift accumulation along berm

Figure 2. View of park illustrating adjacent bulkheads. This photo emphasizes why it is difficult to restore, or maintain, natural beaches when human action has encroached into the intertidal.

Summary

The fifteen projects described in the previous part of this report represent a variety of erosion control techniques, including bioengineering, gravel beach nourishment, and the active use of logs and woody debris - which have received little attention in the published literature on marine shorelines. We found it difficult to categorize or classify these projects since each has unique aspects that distinguish it from others in the study. What we have done, however, is attempted to look at the types of sites and circumstances that allowed the projects to be carried out (ownership, wave energy, geologic setting) and the broad categories of technical approaches (beach nourishment, bioengineering, anchored logs) taken in each case. We conclude with some thoughts and recommendations.

Circumstances

These projects occurred in a wide variety of circumstances - under different types of ownership, for different reasons, under different geological conditions, and on shorelines with unique histories.

Ownership

The private residential sites included individual parcels, homeowner's associations, and cooperative efforts of multiple property owners. The only private commercial/ industrial site was **USG/Thermofibre** in Tacoma, where Superfund status led to substantial agency involvement in remediation and shoreline stabilization work. At **Indian Island** and **Floral Point**, property was owned by the Department of Defense (Navy) and shoreline work occurred under the auspices of cleanup actions. Several sites involved public parks, such as **Blake Island** (State Park), **Salsbury Point** (Kitsap County Park), and **Weather Watch Park** (Seattle City Park). Ownership, at least in itself, does not seem to be a critical factor in developing alternative approaches.

Driver

Most of these projects occurred on properties where erosion control was the property owner's major concern, but where public agencies expressed early concerns about the potential environmental impacts of standard armoring solutions. In some cases, proponents were receptive to alternative approaches, whereas in others the choice of a non-traditional solution was strongly resisted. Willingness to consider softer measures depends to some extent on perceived benefits beyond erosion control. At public parks, such as **Cormorant Cove**, the choice of an alternative solution may also be key to improving public access and enjoyment.

On the cleanup sites - **Indian Island, Floral Point, USG/Thermafiber** - several factors would normally have driven a highly conventional solution. The involvement of large engineering firms, including coastal engineering specialists, and strong concerns about the potential consequences of failure (contamination, federal cleanup laws) typically drives conservative approaches. We believe the fact that alternatives were considered and chosen reflects a collaborative process where consulting engineers and agency biologists were both at the table and where desire for an expedient solution drove project managers to consider compromise. We also suspect that the ability to meet both engineering demands and biological concerns was aided by the financial resources and interdisciplinary talent that Superfund sites can mobilize (Alternative approaches are also being pursued for parts of several other cleanup actions around Puget Sound, including the ASARCO smelter site in Tacoma and the Jackson Park and Manchester/Clam Bay Navy sites in Kitsap County).

Our work did not indicate sites where the softer solution was chosen simply because it was less expensive than a traditional structure, although it appears that in some cases cost savings may have occurred. Unfortunately, cost information was difficult to obtain for many projects and was often difficult to interpret with confidence. As the public and environmental costs of conventional projects are increasingly factored into overall projects costs (typically through design improvements, public review, impact assessments, and mitigation requirements) alternative approaches may become increasingly more economical.

Exposure and Wave Energy

Looking at the physical characteristics of the sites, we note that the examples occur under a variety of energy conditions (defined by wave action, which on Puget Sound is controlled primarily by the fetch and orientation of the beach). It is important to note that high energy sites do not preclude the use of alternatives, although they may limit the range of options available. The success of pocket beaches or of beach nourishment appears to depend on a favorable site orientation - typically a configuration that limits the loss of sediment in a longshore direction.

Geomorphological setting

Several of the sites were located on shorelines that, prior to human modification, were relatively stable depositional beaches (sand spits or locally, *accretion* beaches). Examples include **Salsbury Point**, **Samish Island**, **Blake Island**, **Blakely Island**, **Indian Island**, and **Floral Point**. Interestingly, at each of these sites, the erosion problem occurred primarily in historic fill placed over the backshore and upper beach. Although erosion may affect such landforms naturally, rates are typically slow and rarely threatening (in other words, many of these problems would never have arisen had fill not been placed over the beach in the first place).

A few sites were along shoreline bluffs or eroding banks (**Baum**, **Odermat**, **Dick**, **Place Eighteen**). Such sites differ from beach and other low bank sites in that often the stability of the slope itself is an issue - and may or may not be directly addressed by stabilization of the beach or toe of the slope. Thus at Baum, for example, the portion of the project most relevant to this report is the bioengineering used on the steep slope - but the toe of the slope is marked by a large rock bulkhead.

The **USG/Thermafiber** site was unique in that it occurs on a heavily modified industrial waterway (the mouth of Hylebos Creek) within the larger Puyallup river delta. This site resembles a riverine environment more than a marine one. It is dominated by current action and wake wash, has no true beach, and the entire bank and intertidal slope consists of fine grained delta and floodplain sediments.

Timing

We note that virtually all of the projects discussed in this report occurred in the last several years. This reflects, in part, the tendency of a study such as this to preferentially identify and successfully acquire information for more recent projects and in part, the very real fact that many more of these projects are being considered now due to environmental concerns.

Types of projects

The techniques employed on these sites range broadly and are not always classified readily. This reflects the limited number of projects and their innovative nature. Several general types of projects can be identified, however, including beach nourishment, bioengineering and other applications of vegetation, structural use of drift logs and large woody debris, and modification of traditional structures in order to reduce biological impacts or enhance specific ecological functions.

Beach nourishment

Beach nourishment describes the intentional placement of sand and gravel on a beach, both to replace sediment lost to erosion and to enhance beach function (for recreation, biology, or erosion protection). Increasing the elevation and width of the beach with nourishment can reduce bank erosion, limit backshore flooding, and can restore upper intertidal sand and fine gravel habitats. Although nourishment may result in short-term impacts to beach ecology, it is increasingly viewed as an environmentally preferable approach to managing shoreline erosion (when contrasted to traditional seawalls or revetments). Nourishment's advantages lie in that it mimics native substrates, that it doesn’t alter the underlying beach processes, and that it is typically reversible (if it fails, or is not maintained, the shoreline reverts to its pre-project condition - no permanent structure or alteration occurs).

The application of beach nourishment on Puget Sound has been described by several authors [Downing, 1983; Johannessen, 1996; Shipman, 1996]. Unlike nourishment as it is more commonly employed on sandy, open ocean shorelines (East Coast barrier islands, for example), beach nourishment on Puget Sound typically involves the use of coarse gravel on relatively small sites. Little guidance exists for the design and construction of these coarse-grained gravel beaches in the technical literature.

Samish Beach, **Salsbury Point**, **Driftwood Beach**, **Place Eighteen**, **Blake Island**, **Floral Point** are nourishment projects included in this report. Shipman [in preparation], describes 30 beach nourishment projects throughout Puget Sound (including these), ranging from small gravel pocket beaches on heavily urbanized and modified shorelines to the large artificial island and spit/lagoon complex created with dredged sand at Jetty Island in Everett and the cobble beach feeding project that maintains Ediz Hook in Port Angeles.

Anchoring of large woody material

Large woody material such as logs and root wads have been installed in stream restoration projects for many years, but although logs and woody debris are a fundamental part of Puget Sound beaches, no systematic examination of the use of wood in restoration or erosion control projects on marine shorelines has occurred. The conventional wisdom is that large woody debris generally helps stabilize the beach and may actually enhance deposition of sediment in the proper circumstances, but that during extreme storms and high water levels logs may increase damage to property or aggravate erosion. For decades, property owners have chained or fixed large logs at the toe of the bank to help reduce erosion, but the long-term effectiveness of such actions is not known.

Logs are anchored in a variety of ways, although in the projects described in this report, the method usually involves cabling the wood into deadmen (typically precast concrete blocks - ecology blocks, jersey barriers, parking curbs) buried beneath the beach surface. Screw anchors have also been employed. Examples include **the Dully**, **Blomquist**, **Dick Residences** and **Indian Island**. Anchoring provides a designer and a property owner with a sense of enhanced project durability, but may create some additional problems. In storm events, logs move with wave and tide action and when anchored can result in considerable scour. Cables work loose when beach levels rise and fall. Under extreme conditions, the cables and deadmen may become exposed. Any design using anchored wood should consider likely wave action and fluctuations in beach elevation.

One key question that arises relates to the necessity or the wisdom of anchoring large woody material. Under natural conditions, logs are clearly not anchored in place. Their stability depends on whether the root wad or limbs are attached, the presence of a level berm on which logs can accumulate, and the occurrence of high water levels that can bring logs in or that can float them off a site. It is useful to note that logs are generally not present on beaches that lack a berm (which is a large reason why logs are typically not found on armored shorelines). Attempting to place logs on the sloping portion of the foreshore (below MHHW, for example) can be expected to require anchoring, since logs are rarely stable for long in such a location.

Modification of structural measures

Structures, such as revetments or seawalls, often displace or alter habitat simply by their shape. Their steep slopes result in less habitat within any given tidal range . In addition, the steepness reduces the likelihood of fine-grained sediment retention or deposition and causes wave action to be focused in a narrow zone. These two factors result in little habitat of the sort normally found on gradually sloping sand or gravel beaches. By building a bench into a riprapped slope, the amount of potential habitat at a particular tidal range can be enhanced and the hydraulic conditions changed so as to allow vegetation and retention of sediment (see the **USG/Thermafiber** example).

Another example (not illustrated in this report) might include the construction of a low vegetated bench above a bulkhead and below a higher retaining wall on the bluff face. Increasingly, we find landowners constructing retaining walls up the face of a bluff after a slope failure has occurred above an existing bulkhead (a reminder that bulkheads may do little to prevent an incipient failure of a slope due to hydrologic factors). Such structures typically result in severe impacts to riparian vegetation, but where they cannot be avoided, it may be possible to bench them in such a way as to facilitate the establishment of native woody vegetation as near the toe of the slope as possible - allowing vegetation to hang over the shoreline.

Vegetation and Bioengineering

Riparian vegetation is a key element of shoreline ecological function and has a significant influence on habitat value, both in the riparian zone itself and in adjacent aquatic areas. Vegetation provides physical structure and complexity and surface area, organic input, shade and temperature modulation, insects (fish prey) and wildlife habitat. It also provides a transitional zone between upland and aquatic areas, filters surface runoff, retains sediment, and supplies large woody debris to the aquatic system.

Natural shorelines clearly vary on the degree and character of riparian vegetation - for example, the micro-dunal backshore of a sand spit differs markedly from a heavily forested bluff. One objective of soft structures is generally to restore some element of natural vegetation and riparian function to the shoreline. The simplest approach is to encourage revegetation in native species and to design stabilization measures that facilitate this. Concrete bulkheads with grassy lawns above clearly diminish riparian function, whereas rock bulkheads that incorporate woody material and that are accompanied by aggressive planting of appropriate vegetation above and behind them provide riparian function - at least to some extent.

Bioengineering[4] refers to the use of vegetation as an active component in engineering solutions to unstable slopes and shoreline erosion. It has receive considerable attention in river and stream work [Gray and Sotir, 1996; Soil Conservation Service, 1992; Hollis and Leech, 1997; Barker, 1995], but very little work has been done on its application to marine settings [Ranwell, 1983]. The Department of Ecology publishes two booklets on the use of vegetation on coastal bluffs - one applies to managing existing vegetation [*Vegetation Management on Coastal Bluffs*, Menashe, 1993]; the other describes more active biotechnical approaches to slope stabilization and landslide repair [*Slope Stabilization using Vegetation*, Myers, 1993].[5]

Biotechnical approaches include a variety of techniques, including wattling, live staking, and brush boxes that increase root strength in soils, interconnect soils units to reduce potential for larger failures, and reduce erosion by surface runoff, groundwater seepage, or waves and currents. Bioengineering on coastal slopes may not differ significantly from bioengineering on northwest rivers and streams - the soils and vegetation are similar - except on highly exposed shorelines where salt influence is extreme.

The primary difference arises in the treatment of the slope toe. Numerous plants and trees can withstand periodic inundation with fresh water during riverine flood events, but few native woody species can survive in tidal waters, limiting the options for using vegetation at the toe of the bank. River and marine shorelines differ in several other important ways that should influence the selection and application of bioengineering methods developed for fluvial systems: 1) river banks are exposed to more extreme inundation than marine shorelines due to floods; 2) riverbanks are eroded by current, whereas the toe of marine banks are eroded by wave action - which is very different in its direction and behavior; and 3) wave-dominated shorelines usually have beaches, whereas erosional riverine banks do not.

The **Baum Residence** in Thurston County is a good example of an aggressive bioengineering solution to a steep slope, used in conjunction with soil-nailing. It should be noted, however, that the toe of the slope is not bioengineered, but rather is stabilized with a substantial rock seawall. In this case, bioengineering

[4] The terms biotechnical slope stabilization and soil bioengineering are preferred, in part because the term *bioengineering* means many very different things in other contexts, such as in agriculture or medicine.
[5] A third booklet in this series addresses drainage issues on coastal bluffs and their importance to slope stability (*Groundwater Management on Coastal Bluffs*, Myers and others, 1995).

is intended to stabilize the slope while providing limited riparian functions, but the project does not address potential beach impacts associated with the bulkhead or with the permanent stabilization of the slope. It illustrates techniques, however, that may be widely applicable to bluff properties where bulkheads already exist or where bulkheads are likely to be approved in the future.

Opportunistic beaches and setback bulkheads

Habitat impacts often occur simply due to the waterward position of a hard structure. By relocating an existing structure farther landward, considerable habitat value can be recovered. By constructing a new structure farther landward, some habitat loss can be avoided. In addition, the farther landward a structure is constructed, the less wave energy it is exposed to and the less robust, and thus expensive, the structure need be. Often, the sacrifice of ten to twenty feet of lawn may allow the creation of a viable natural beach and avoid the need to spend money on a standard bulkhead. **Weather Watch Park** in Seattle illustrates how a relatively natural beach can exist on an otherwise heavily armored shoreline, simply because the beach profile remains relatively undisturbed. **Cormorant Cove**, when completed, will take advantage of the same principle by removing much of an existing bulkhead and restoring a more beach gradient. Another West Seattle example of this occurs at Lowman Beach Park, where the removal of 100 feet of concrete bulkhead allowed a beach to rapidly re-establish.

Combination approaches

Many of these projects combine approaches. At some sites, different measures were used on different sections of shoreline (at **Indian Island**, three basic treatments were used for three different segments of the beach, based primarily on changes in exposure and different existing geometries). In other situations, one measure may be adopted lower on the site while a second is used on landward areas. The combination of a rock bulkhead at the toe of a slope with a bioengineered slope, as at **Baum Site**, or of beach nourishment with backshore plantings, as at **Driftwood Beach (Blakely Island)**.

Nourishment projects often incorporate structural elements, such as groins (**Samish Beach**) or existing pockets in otherwise riprapped shorelines (**Cormorant Cove**). At **Salsbury Point**, nourishment was placed adjacent to a modified rock bulkhead. Another variation is demonstrated at **Blake Island**, where nourishment will be accompanied by a largely buried sheetpile retaining wall. This wall appears to serve little purpose except as a landscape feature as the project is built, but provides a structural backup in case the nourishment does not perform as anticipated. Clearly, such a measure adds appreciably to the cost of a project. Also, any structure built to serve as a seawall in the future must be built to the appropriate standard, even though it maybe tempting to compromise on the design of a structure that will be largely hidden when first built.

Monitoring

Monitoring implies a periodic survey or review of a project. It may be as simple as qualitative observations and photographs or it may entail extensive and scientifically rigorous biological surveys of the beach. Typically, monitoring might fall between these end points. Few of the projects described in this report have been regularly monitored and even fewer have a formal monitoring plan as a condition of their approval. Projects in this report that had monitoring requirements include **Driftwood Beach (Blakely Island)**, **Blake Island**, **Indian Island**, **Samish Beach**, and **Floral Point**. A number of projects have been monitored informally by those involved in their design, largely in an effort to learn how the projects behave and to use this information to guide future designs.

Monitoring is valuable for several reasons:

- Monitoring of project performance provides the property owner with a way of identifying problems and the need for future action. In some cases, monitoring is the property owner's tool for demonstrating that a soft approach isn't working and that a traditional solution may be appropriate or necessary.
- Projects that involve vegetation or beach nourishment may have a maintenance component. Monitoring can guide the frequency and extent of periodic maintenance and can guide future adjustments to the project's design.
- Monitoring is a tool that agencies can use for evaluating the impacts of a project on ecological resources or on neighboring beaches.
- Monitoring provides the broader community of consultants, scientists, and resource managers with critical information that can be used to better understand the application of specific techniques and the effectiveness of project requirements and conditions. Monitoring allows everyone to learn from both the successes and failures of projects and facilitates, which we hope leads to better projects and better regulation.

There are no standard guidelines for monitoring beach projects on Puget Sound, nor even general agreement on what aspects of a project require monitoring. The objectives for monitoring vary from one project to another and reflect the nature of the particular project. For example, vegetation-based projects may include a monitoring element to document plant survival and the need for replanting as well as a measure of the extent to which the project provides riparian functions such as shade or insect production.

Beach projects, and nourishment projects in particular, benefit from periodic surveys of beach topography that allow evaluation of sediment movement, changes in beach elevation, storm erosion, the potential need for future renourishment, and possible off-site beach changes. Beach profiles can be fairly simple to collect, once a basic reference system is established. Annual surveys provide information about chronic beach changes, but often it is necessary to observe the beach semi-annually in order to determine seasonal variations.

Biological monitoring of shoreline projects is made difficult by the lack of understanding of biological processes in this environment and by the increased complexity of the types of observations and statistical procedures that must be followed to draw valid conclusions. Significant inferences about biology can be made from physical observations of beach profile, short-term disturbance (storms and landslides), or sediment size, but what is increasingly needed is better guidance as to what biological variables should be monitored and how to best incorporate this monitoring at practical level.

Project performance

Most of the projects examined in this report were built recently and there has been too little time to allow assessment of their success. In addition, few are being actively monitored (see previous section), so there is little information from to which to evaluate performance, other than qualitative observations of distinct features such as erosion scarps, exposed anchor cables, or movement of placed logs.

With beach nourishment projects [Shipman, in preparation], we are finding that success is relative -- for example, a project may be viewed as successful in addressing past erosion, yet fail to achieve biological restoration. Also, standards of success vary. Most nourishment projects gradually erode and generally require renourishment. Some individuals accept this as part of the design whereas others see this as an indication of a project that cannot be naturally sustained. Failures do not necessarily reflect on the technique itself, but the appropriateness of the choice for the site or the design of the overall site. Some soft-bank projects succeed locally in reducing the biological impacts that might have resulted from a traditional seawall, yet do not address more systemic ecological concerns, such as the long term supply of sediment to the littoral system.

Perhaps in an area of innovation and experimentation such as alternative erosion control, we should view as successful those projects where the documentation of the project is sufficiently rigorous so that we can learn from our mistakes.

Conclusions

The fifteen projects outlined in this report illustrate a number of techniques for managing shoreline erosion that reduce the environmental impacts associated with conventional erosion control measures such as bulkheads and rock revetments. Few of these projects have been in existence long enough for final conclusions to be drawn about their success, but the initial success of most has been favorable. All warrant close observation during coming years.

Based on this study, we offer the following recommendations:

- *Monitoring*. Monitoring is key to evaluating both the impacts and the performance of shoreline projects and should be routinely carried out. Some basic guidelines for monitoring reports would benefit both project proponents and regulators. This is particularly true in the case of biological monitoring, where much work needs to be done to establish appropriate measures and methods of assessing beach ecology. Monitoring should include careful documentation of pre-project condition and the project as actually constructed. It may be helpful for the state to provide assistance in monitoring or at least in compiling and reviewing monitoring data.

- *Outreach and education*. There is great demand for information about alternative approaches from property owners, consultants, local governments, and resource agencies. A series of short information sheets might be prepared that describe, in fairly general terms, the types of approaches outlined in this report. Many property owners and project applicants would find a resource guide that identifies potential consultants and helps walk people through the process of selecting a method. This information could be very effectively distributed on the internet. A publication similar to those already produced by the Department of Ecology on Vegetation Management and Drainage would be valuable.

- *Engineering Guidance and Design Standards.* Given the wide variety of circumstances and types of projects and the lack of technical data on which to base designs, it may be impractical to develop detailed design and construction guidelines. In addition, detailed requirements may limit the ability of applicants and designers to propose and develop innovative approaches. What might be more useful is some broader guidance as to the types of projects that are appropriate in what types of settings, the types of information that should be collected and presented in an application and design, and sources of technical information and expertise on specific techniques.

- *Demonstrations*. Efforts should be made to encourage and publicize projects that employ environmentally friendly techniques. Agencies should investigate means of providing funds or incentives to encourage demonstration projects. Resource agencies might consider collaborating with parks departments (state and local) and other public landowners on shoreline erosion projects.

- *Regulatory Requirements*. Increasingly, resource agencies are discouraging traditional seawalls and revetments and promoting the consideration of softer methods. Unfortunately, whereas traditional erosion control methods often receive minimal scrutiny and may be exempted from more rigorous permit review, many preferred methods are not. Regulations should encourage, not discourage, the selection of more environmentally benign measures.

Finally, this report should be used with caution. The inclusion of a shoreline project here is neither an endorsement of the design for application elsewhere nor a guarantee of a project's likely success. We welcome the use of this document as an educational tool to inform people of the wide range of options available and provide reassurance that others have also been willing to try creative solutions. On the other hand, we discourage readers from adopting specific design elements from these examples without careful consideration of their site and the nature of their problem, presumably with professional guidance. The fact that alternatives may be applicable in *some* situations does not mean that an alternative is appropriate in *all* situations.

Many of the measures described in this report entail significant modifications of the shoreline and of natural shoreline processes. Many will require ongoing maintenance and few guarantee that a property will never experience erosion or storm damage. The preferred alternative on most shoreline sites remains adapting the land use to the natural processes on a site and avoiding manipulation of the shore.

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Glossary

Armoring - Term used to describe the construction of seawalls or revetments along a shoreline.

Backshore - The portion of the beach beyond the reach of most high tides and landward of the berm.

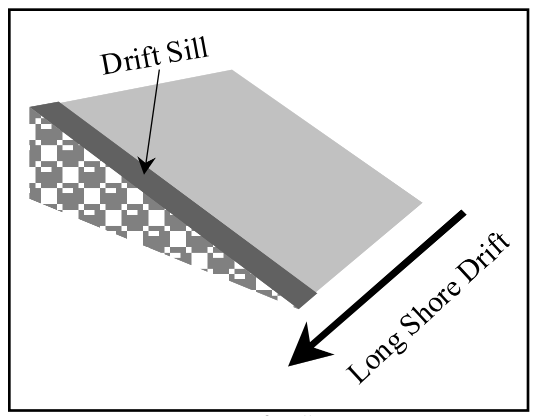
Berm - The relatively level bench found high on a beach where sediment is deposited and, at least on Puget Sound, where drift logs accumulate.

Breakwater – A structure built specifically to protect a boat basin or harbor from wave action. These are often constructed with rip-rap.

Bulkhead – A wall, usually of rock, concrete, or wood, built parallel to the shoreline to protect the bank from wave erosion and to retain soils.

Bull rock – Rock from a river or stream. It is naturally rounded, unlike quarry spall.

Drift Sill – A groin built level with the beach surface. Designed to allow bypassing of littoral sediment while maintaining a prescribed beach grade.



Drift Sill

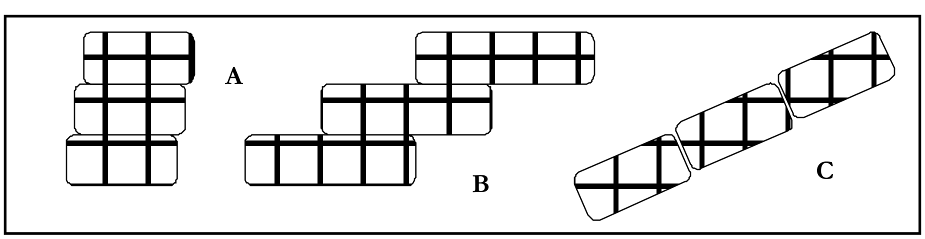
Ecology Block – Large precast cement blocks that are approximately 4'L x 2'H x 2'D. They have a re-enforcement steel (rebar) loop embedded in them for lifting and anchoring.

Feeder Bluff: A eroding bluff that provides sediment to the beach and to long shore drift.

Fish Rock (Fish Mix) – A gravel mix that is of suitable size for bait fish spawning (pea gravel).

Fishtrap Staples – Heavy staples used to temporarily anchor cable to logs while cable clamps are being applied.

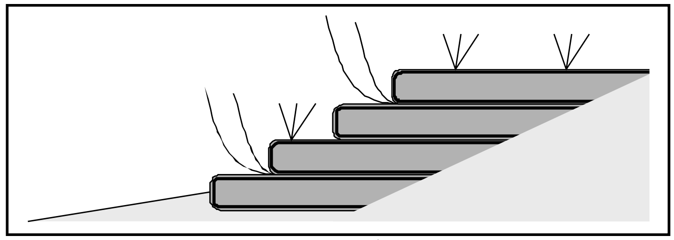
Gabion: An erosion protection system that employs wire mesh baskets filled with rock to protect shorelines. These may be stacked to create a bulkhead (A), set up like the geogrid to create a stepped revetment (B) or laid flat to create a smooth slope (C).



Gabions

Geogrid – A bank stabilization system composed of multiple *geogrid lifts* and a planned vegetation system.

Geogrid lift – A layer of compacted soils wrapped in geotextile (usually a combination of both natural fiber and plastics).

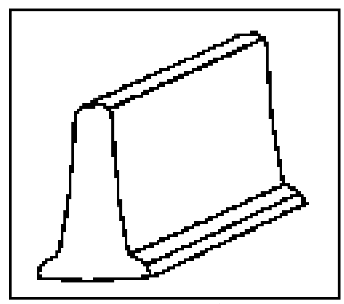


Geogrid

Geotextile Fabric – Fabrics used in soft bank structures that serve several purposes. Coir and other natural fiber fabrics (woven straw matting) are used to secure sediments and reduce erosion temporarily as vegetation takes hold. They are designed to deteriorate after the establishment period has passed (~3 years). Filter fabrics are used to maintain fine sediments (behind a bulkhead for example) while allowing water to pass. This prevents the loss of fines from projects while still allowing the release of hydrostatic pressure that may develop. Tensar® and other plastic type materials are used to provide long term structural support.

Groin – A structure, built perpendicular to the shoreline, designed to trap sand being moved along the shore by long shore drift.

Jersey Barriers – Sectional concrete barriers that often used in highway construction projects.



Jersey Barrier

Parking Curb – The cement stops that are often found at the head of parking spaces. They have two or three holes through them that cable can be fed through for anchoring logs into the beach.

Quarry Spall – Rock fragments obtained from quarry operations - typically angular and several inches to a foot or so in size.

Rip-Rap – Rock boulders placed to form a breakwater or revetment.

2-man Rock – A classification for rock size, based in theory on the number of men it would take to lift the rock.

Revetment – Rock or concrete armor placed on a slope to dissipate or resist wave action.

Sacrete – A structure made of bags filled with hardened concrete.

Seawall – A wall built parallel to the shore to protect against wave action - similar to a bulkhead but of a more massive scale.

Soil Nails - Soil Nails are a method for deep slope stabilization. They are epoxy-coated rebar driven 15 – 30' into the bank and then encased in a 4" diameter shaft of cement. The nails provide the most support at the face of the bluff where the slope is weakest.